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WADC TECHNICAL REPORT 52-223

EFFECT OF JAW RESTRICTION ON SPEECH INTELLIGIBILITY

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AERO MEDICAL LABORATORY

SEPTEMBER 1952

WRIGHT AIR DEVELOPMENT CENTER

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EFFECT OF JAW RESTRICTION ON SPEECH INTELLIGIBILITY

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Aero Medical Laboratory

September 1952

RDO No. 695-63

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

FOREWORD

This work was accomplished in the Bio-Acoustic Section under the authority of RDO No. 695-63, Effects of Vibration on Air Force Personnel, administered by the Biophysics Branch, Aero Medical Laboratory, Directorate of Research, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, under the direction of Horace O. Parrack, Major, USAF, Project Scientist.

The appreciation of the author is hereby expressed to Dr. John W. Black, Head of the Speech Science Department, Ohio State University for his counsel and interest, and for making available the speaker and listener forms used in this study.

ABSTRACT

The effect on speech intelligibility of varied amounts of jaw restriction and loudness levels was studied in experiments with 24 speaker and 212 listener subjects.

Speech intelligibility forms were read and recorded and subsequently scored by the listeners.

Results show that under the conditions of this experiment the effect of jaw restriction on speech intelligibility is negligible.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDING GENERAL:

Robert H. Blount

ROBERT H. BLOUNT
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

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INTRODUCTION

Inter-plane and air-to-ground communication has always been less effective than desired. Many difficulties result largely from the presence of high ambient noise levels in aircraft and possibly from the limitations imposed by personal equipment used by air crew members. These problems have increased rapidly with the increased speed and complexity of modern aircraft and examination of existing conditions together with estimation of communication requirements for future high performance aircraft indicates even greater difficulties to come. Increased speeds will not permit time for repetition of messages, ambient noise levels will probably not decrease materially and there is a possibility that they may be greatly increased.

In view of the need for better voice communication, every effort is being made to devise advanced methods including improved design of microphone, headphone, transmission and amplification components. However, all of these improvements of the communication system will be to no avail if personal equipment, such as the oxygen mask, oxygen helmet, crash helmet and other devices with which the communication system must be integrated so distort the speech signal, originated by the speaker, that the intelligibility is lost. Many of these personally worn devices restrict the motion of the jaws and compress the facial muscles. Therefore, there is a high probability that the speech signal may be greatly distorted at its source. For this reason it is considered essential to investigate the effect on the speech signal of known controlled amounts of jaw restriction. This paper deals with one of a series of experiments in which word intelligibility was used as a measure of the degree of interference to voice communication of various amounts of jaw restriction. It should be realized that these experiments are concerned with only one of several mechanics by which the speech signal may be distorted when the speaker is wearing standard Air Force personal equipment.

SECTION I

METHODS

Controlling Jaw Motion:

Several methods were tried for holding the head fixed so that the motion of the jaw was subject to known and controlled amounts. As a result of these trials a procedure was developed which permitted fixing the head and controlling jaw motion in the following amounts: (1) no restriction; (2) maximum of 1/4 inch; (3) maximum of 1/8 inch; (4) complete restriction. The head holder and the manner of its use are pictured and described in Appendix I (Part A) together with a limited discussion of the various unsatisfactory methods tried.

Control of Loudness Levels:

Loudness levels of 70 db (decibels), 80 db and 90 db were selected. An indicator was used by which the speaker could monitor his own speech in order to maintain the required levels. A discussion of the determination and control of the loudness level is found in Appendix I (Part B).

Intelligibility Test Material:

The intelligibility test is comprised of Forms A and B. Each "speaker form" consists of twelve (12) lists of twenty-four (24) words each and the lists are designed to be equally difficult. The words are arranged in eight 3-word groups in each list. Each 3-word group is read with a carrier phrase i.e. "number four go lady break" and as a sentence without pauses. Listeners scored the recorded speaker data on "listener forms" which have four (4) words for each word the speaker has read. These words are ones that are most often mistaken for each other, thus making it necessary to hear all the sounds in each word to identify it correctly. Samples of speaker and listener forms will be found in Appendix II.

SECTION II

EXPERIMENTAL PROCEDURE

Recording Intelligibility Lists:

With the subject seated in the chair the head holder was lowered in place and adjusted as described in Appendix I (Part A). A six inch by ten inch card containing lists of words was attached eighteen (18) inches in front of the subject on a level with his eyes. Two neon bulbs were located at one side of the card. Subject was given a brief description of the purpose of the experiment and then the following instructions:

> "You will now read the intelligibility lists. Read your number, Intelligibility Form (A or B) and list number, then proceed to read the different lists under the various amounts of jaw restriction. Under each condition of jaw restriction you will read at three levels of loudness which you will monitor by these neon bulbs. Keep one bulb glowing constantly and brightly and one just flickering off and on. Read each list thusly (exp. reads two 3-word groups with carrier phrase). Remember, do not pause after the carrier phrase. I will give you a hand signal when you are to read each 3-word group -- there is a time delay of seven and a half seconds between the time you begin to read one list and the time you begin to read the next one. Your loudness level, in addition to being indicated by the neon bulbs, will be monitored by the equipment operator on a voltmeter, he will raise or lower his hand to signal necessary changes in your loudness level. As conditions of jaw restriction and loudness level change, you will be given time to establish new levels. Nowgo through this practice list to check all instructions. Use all the jaw movement allowed by the chin bar. Speak naturally."

The order in which the speakers read the intelligibility lists was rotated with each subject so that the same lists would not always be read under the same conditions of jaw restriction and loudness level. The order of jaw restriction conditions used by all speakers was the same -- from the unrestricted condition to 1/4 inch to 1/8 inch to closed position.

In all conditions speakers utilized the maximum movement permitted. The order of levels of loudness for each jaw restriction position remained 70 db, 80 db and 90 db for all speakers.

Recording Equipment:

The speech signal was picked up by a high fidelity microphone twelve (12) inches in front of the speaker's mouth and recorded on tape at a speed of fifteen (15) inches per second. Equipment pictured and described in Appendix I, (Part C).

Speakers Subjects:

Twenty-four speaker subjects were selected from Aero Medical Laboratory personnel and from pilots of Flight Test Division (WADC). An effort was made not to use speakers whose regional dialects were "overly" pronounced.

Listener Subjects:

Listener subjects from the 2750th Processing Squadron and from the Aero Medical Laboratory, WPAFB were used to determine intelligibility scores for the speakers. The subjects from the Processing Squadron were enlisted personnel, recently drafted and awaiting assignment, and represented a fair sample population of Air Force Airmen. The Aero Medical Laboratory group was composed of medical men, technicians and officers.

Procedure Used to Gather Speaker Data from Listeners:

Recorded speaker data at an average level of 73 to 75 db and a flat spectrum noise of 70 to 72 db, both measured at the ear, were presented simultaneously through a speaker. Thus, the signal to noise ratio was about three db at the ear for all listeners.

Each group of nine listeners scored speakers reading Intelligibility Forms A and B. Listeners did not hear the same Intelligibility Form more than once. The scores of each listener were checked and the number wrong for each of the twelve conditions was recorded on an IBM card with other necessary identification data including speaker and listener number and listener's age. The data was then treated statistically.

SECTION III

RESULTS

Statistical Analysis and Discussion

Summary:

Twenty-four speakers read twelve equally difficult sets of twenty-four words each, to groups of from eight to ten listeners, each set of words being read under a different pair of conditions of voice level (70, 80 or 90 db) and jaw restriction (no restriction, 1/4 inch freedom, 1/8 inch freedom and complete restriction). The listeners, in each case,

chose one of the four words on a printed form as the spoken one; this section of the report is an analysis of the number of errors made by the listeners in selecting the correct words as spoken by the speakers.

1. The overall pattern of error frequencies is given in Tables Ia, Ib & II.

Table Ia shows the average number of errors made by the 212 listeners under each of the twelve pairs of conditions, the combined average for each voice level, and the combined average for each level of jaw restriction. These data are given in terms of actual numbers of words and as percentages of the sets of twenty-four words.

Average Number of Errors (All Listeners)

-1-

	Voice Level 70 db	80 db	90 db	
None	9.66	9.02	8.75	words
1/4"	10.47	9.23	9.72	words
1/8"	10.55	9.55	8.78	words
Full	10.07	10.21	10.42	words

	Voice Level 70 db	80 db	90 db	
All Restrictions Combined	10.18	9.50	9.42	words

	Jaw Restriction None	1/4"	1/8"	Full	
All Levels Combined	9.14	9.79	9.62	10.23	words
All Conditions				9.70	words

(Note: " = inches)

TABLE Ia

-2-

	Voice Level 70 db	80 db	90 db	
None	40.2	37.6	36.4	%
1/4"	43.6	38.4	40.5	%
1/8"	44.0	39.8	36.6	%
Full	42.0	42.5	43.4	%

	Voice Level 70 db	80 db	90 db	
All Restrictions Combined	42.4	39.5	39.3	%

	Jaw Restriction None	1/4"	1/8"	Full	
All Levels Combined	38.1	40.8	40.1	42.6	%

All Conditions	40.4	%

TABLE Ia (Cont'd)

No. of Listeners: 212 (Except for 70 db, 1/4" for which N=202)
(Note: " = inches)

Table Ib gives the range of the numbers of errors (expressed as percentages) made by individual listeners and the range of the average number of errors made by the twenty-four listener groups (i.e., those listening to the same speaker), these ranges being computed for each of the twelve pairs of conditions.

Range of Number of Errors for the Individual Listeners

-1-

	Voice Level 70 db	80 db	90 db	
None	8-79	12-79	4-79	%
1/4"	8-75	8-75	8-75	%
1/8"	12-83	8-79	4-71	%
Full	0-87	12-79	4-79	%

-2-

	Voice Level 70 db	80 db	90 db	
None	20-57	20-55	18-60	%
1/4"	24-58	24-56	18-56	%
1/8"	27-69	23-59	23-49	%
Full	14-63	24-60	29-62	%

(Note: " = inches)

TABLE Ib

Table II presents a comparison of the errors made at each pair of conditions with those made under conditions which are different with respect to either voice level or jaw restriction, but not both. The top half of this table shows the differences between the several voice levels for constant jaw restriction level; the lower half of the table shows the differences between jaw restriction levels for constant voice levels. In addition to the actual differences in the averages, this table includes t-values for each of these differences. This statistic is the standard measure of the statistical significance of such differences.

Differences Between Average Number of Errors at Different Voice Levels (for Constant Jaw Restrictions)

Jaw Restriction		Voice Levels: 70 db - 80 db	70 db - 80 db	80 db - 90 db	
None	$\bar{d}$:	0.64	0.91	0.27	words
	t:	2.64	3.75	1.11	
1/4"	$\bar{d}$:	1.24	0.67	-0.49	
	t:	5.11	2.71	-2.02	words
1/8"	$\bar{d}$:	1.00	1.77	.77	words
	t:	4.12	7.24	3.17	
Full	$\bar{d}$:	-0.14	-0.34	-0.21	words
	t:	.56	-1.42	-0.86	

Differences Between Average Number of Errors at Different Jaw Restrictions (for Constant Voice Levels)

		no-1/4"	No-1/8"	No-Full	1/4"-1/8"	1/4"-Full	1/8"-Full	
70 db	$\bar{d}$:	-0.72	- .89	-0.41	-0.18	0.41	0.48	words
	t:	-2.97	-3.66	-1.69	- .74	1.63	1.96	
80 db	$\bar{d}$:	-0.21	-0.53	-1.19	-0.19	-0.98	-0.66	words
	t:	-0.85	-2.18	-4.90	-1.32	-4.05	-2.72	
90 db	$\bar{d}$:	-0.97	-0.03	-1.67	.94	-0.70	-1.64	words
	t:	-3.99	-0.12	-6.87	3.87	-2.88	-6.75	

(Note: " = inches)

TABLE II

Significant values of t: values of 1.97 or more occur by chance once in twenty times, values of 2.60 or more occur by chance once in one-hundred times. Interpretation of the significance of the values of t must recognize that these significance levels are based on the probable values of an isolated value of t and not on the probable values of the largest or any otherwise specially selected value from a group of t's.

Note: $\bar{d}$ is the average number of errors at the first indicated condition minus the average number of errors at the second indicated condition. Thus, the first value of $\bar{d}$, shows that the average number of errors made at 70 db was 0.64 words greater than the average number of errors made at 80 db when there was no jaw restriction.

These tables, together with Table III (Appendix III) which summarizes the average and range of percent errors by speakers, show that the performance of the various listener groups was fairly consistent for each pair of conditions with the average percentage of errors at each of the twelve pairs of conditions running about 40%. The range of these averages is from 36% to 44%: the best average performance (90 db and no restriction) being less than two words better than the worst average performance (70 db and 1/8 inch freedom.)

In contrast to these relatively uniform averages, the range of the individual listener errors and the range of the error averages of the listener groups are quite large; for the different pairs of conditions, the poorest individual performance averages about 70% more errors than did the best one, and the poorest listener group averages showed about 35% more errors than did the best ones.

Interpretation of these data should include recognition of the role that chance ordinarily plays in tasks of this kind. The listener who does not hear a word intelligibly still has one chance in four of giving a correct answer since he is forced to choose between only four words. One may expect, therefore, that the observed errors represent only three-fourths of the occasions on which the listener actually could not make out the word which was read.

Viewed in this light, the data suggest that the listeners, on the average, failed to make out the words about (4/3 of 40%) or 53% of the time, and that the worst individual performances ranged from one word better than chance (90 db, 1/8 inch freedom -- 71% errors) to three words worse than chance (70 db, full restriction -- 87% errors).

Further and more rigorous analyses of these data will be given in the following paragraphs; at this point one can, however, summarize the results as follows:

(a) The average performance was much the same at each pair of conditions.
(b) Individual performances at each pair of conditions ranged from almost perfect to no better than indicated by random marking of the answer sheet.

2. The possible effect of age on the listener's performance was investigated by comparing, under each of the twelve pairs of conditions, the numbers of errors made by the eldest and youngest members of each of the listener groups in which the age spread was at least ten years. The results, given in Table III, show no evidence of an age factor under the conditions of this experiment.

Comparison of Errors Made by Eldest and Youngest Listeners in Each of 22 Listener Groups

		Voice Level 70 db	80 db	90 db	
None	$\bar{d}$:	.50	- .82	.64	words
	t:	.57	.92	.91	
1/4"	$\bar{d}$:	.62	-1.09	.91	words
	t:	.74	1.97	1.29	
1/8"	$\bar{d}$:	.68	.14	- .59	words
	t:	.86	.15	.68	
Full	$\bar{d}$:	- .23	- .14	.00	words
	t:	- .27	.19	.00	

All conditions combined: $\bar{d}$ =.05 words.
Average difference in age: 16.3 years.

(Note: " = inches)

TABLE III

Note: $\bar{d}$ = (Average number of errors made by the eldest group member) - (Average number of errors made by the youngest group member.) Negative values indicate fewer errors for the elder men than for the younger men.

Significant values of t: values of 2.07 or more occur by chance once in twenty times, values of 2.82 or more occur by chance once in one-hundred times.

3. For guidance in the further analysis of the data, the correlation between the individual listener's performance under different conditions of voice and jaw restriction levels was made. A somewhat rough computation of this correlation gives a value for the correlation coefficient of 0.14. Thus it appears that there is little consistency in each listener's performance under the twelve pairs of conditions, so little, in fact, that one may assume that the results are much the same as those which would have been obtained had the personnel of each listener group been different for each of the twelve pairs of conditions.

It may be worth noting that the variability between listener's performances for different voice levels (constant jaw restriction) was virtually identical with that for different jaw restrictions (constant voice level.)

4. The standard comprehensive analysis of data such as those of this study falls in the form of an analysis of variance. (Table IV.)

Analysis of Variance [1]

	-1- Sum of Squares	d/f	s^2	
Between Groups[2]	11,095.90	215	51.61	F = 7.29
Within Groups	12,240.89	1728	7.083	(Error)
Total	23,336.79	1943	12.01	

-2-			s^2/error	s^2/SxLxR
Between Speakers	6,588.76	17	387.57	54.72	24.28
Between Levels	178.26	2	89.13	12.58	5.58
Between Restrictions	214.57	3	71.52	10.10	4.48
Levels X Restrictions	536.53	6	89.42	12.62	5.60
Speakers X Restrictions	1,065.90	51	20.90	2.95	1.31
Speakers X Levels	883.35	34	25.98	3.67	1.63
Speakers X Levels X Restrictions	1,628.53	102	15.96	2.25	
Total between groups	11,095.90	215			

1 Based on 18 listener groups of 9 listeners each
2 A group is a listener group at a particular pair of conditions of voice level and jaw restriction

TABLE IV

Such an analysis considers the variation among the data by assuming that each individual's performance for a given pair of conditions varies from the overall average as a result of several factors:

a. a factor attributable to noise level.
b. a factor attributable to jaw restriction level.
c. a factor attributable to the speaker.
d. a factor, remaining after both the voice level and jaw restriction factors have been taken into account and attributable to particular combinations of voice level and jaw restriction.
e. a factor, similar to d, attributable to particular combinations of voice level and speakers.

f. a factor, similar to d and e, attributable to particular combinations of jaw restriction and speakers.
g. a factor remaining after all the above factors have been taken into account, and which is the result of three way combinations of voice level, jaw restrictions and speakers.
h. a factor, essentially one of error, associated with the inherent variability of individual performances under common conditions of speaker, voice level, and jaw restrictions.

The question of whether these factors exist is judged by the values listed in the table under the heading s^2. If a factor does not exist, the value of s^2 listed opposite it should be approximately the value of s^2 listed opposite "within groups," 7.08 in this case. One school of thought holds, however, that the practical existence of a factor is to be determined by comparing the value of s^2 with the value of s^2 shown opposite Speakers x Levels x Restrictions (factor g, above).

By either standard, the factors attributable to speakers' voice levels, restrictions, and levels and restrictions clearly exist. Factors attributable to speakers and restrictions and to speakers and levels are less well established; in any event these factors, if they exist, are relatively unimportant.

The essential fact emerging from this analysis is simply a confirmation of the impression given by the earlier presentation of the data that the one crucial factor in determining the average performance of a group of listeners is the speaker. All other factors are relatively unimportant as compared to the speaker factor.

Another summary of the results may be given in terms of standard deviations (these standard deviations are closely related to the data of Table IV.). The estimated standard deviation of:

errors made by individual listeners (same speaker and conditions):	2.66 words
average number of errors - different speakers (same conditions):	1.89 words
average number of errors - different voice levels:	0.37 words
average number of errors - different jaw restrictions:	0.38 words

Here again, the differences between voice levels and between jaw restrictions seem minor in contrast to the differences between speakers.

Conclusions and Recommendations:

The physical restriction of jaw movement as controlled in this experiment has an insignificant effect on speech intelligibility. However, further studies, using prolonged jaw restriction and/or longer speaking periods more closely approximating those which may be encountered in actual flight, might yield different results. Likewise, an investigation of the effects on speech intelligibility of noise, altitude and pressure breathing in combination with

jaw restriction might be indicated. Further jaw restriction studies could also be designed to take into consideration such factors as the compression of the facial muscles, the resonance characteristics of the cavity of the oxygen mask and others which may result from the wearing of personal equipment items.

The differences between individual listeners and speakers as shown in this experiment might be somewhat minimized by an adequate voice communication training program for all flight personnel.

APPENDIX I

Instrumentation and Calibration

Part A. Controlling Jaw Motion:

The method of holding the head fixed and controlling the amount of jaw movement consisted of a 6 foot 1 inch by ten inch board "A" attached to the wall by hinges so that it was level with the top of the head (see Fig. 1) of the subject when seated. Twenty-four inches from the free end a 24 inch by 1 inch by 10 inch board was attached at right angles. To each A & B board a 12 inch 1 inch by 10 inch board C & D was attached with an adjustment of 1½ inches vertically for C and 1½ inches horizontally for D. These two boards had elliptical shaped holes covered with doeskin into which the top and the back of the head were fitted to eliminate excessive scalp motion. A wooden form covered with latex rubber was connected to board "A" by means of a hinge 6 inches in front of the forehead. The free end was designed to fit the bridge of the nose and the bones over the eyes and was adjustable vertically and horizontally. To control jaw movement two 18 inch by 1 inch aluminum angle strips F & G were attached to each side of board "A" 6 inches from the free end. An aluminum chin bar H covered with 1/4 inch foam rubber and doeskin was attached to F & G through a 2 inch vertical slot by means of which it could be adjusted to the chin bar. Previously attempted methods of holding the head fixed and controlling jaw movement included (1) use of helmets i.e. protective helmet (Type PIA) conventional (Type A-10A) and helmet liners strapped by various means to chairs and walls. Chin straps and bars were also attached to helmets; (2) use of straps and net material attached to "supine chair" with board on top of head; (3) a plastic form the general shape of the head but 2 inches larger with a system of screws to hold the head at many points; (4) a fabricated plastic form with an adjustment on the bridge of the nose and a net and board arrangement attached to the supine chair and pilots chair; (5) a solid board in back of and above the head with aluminum braces and chin bar attached to the pilots chair. None of these methods proved entirely satisfactory but all led to the design of a usable model.

Determination of and Control of Amount of Jaw Restriction:

With the subject seated in a chair and the head holder adjusted, test material was read at various loudness levels as measured by a GRC 759 Sound Level Meter with microphone placed 12 inches in front of the speaker's mouth. By adjusting the chin bar it was subjectively determined that jaw restriction permitting more than 1/4 inch maximum amplitude at various loudness levels had no significant effect on speech. Therefore, the following conditions of jaw restriction were chosen for this experiment: (1) no restriction; (2) maximum of 1/4 inch freedom; (3) maximum of 1/8 inch freedom; (4) full restriction. These distances were determined by drawing a pencil mark on the lower teeth at the point reached by the upper teeth in normal "closed mouth" position, and inserting wooden wedges to achieve the proper distance as measured from pencil mark to the lower edge of the upper teeth. The chin bar was then adjusted

tightly under the chin, the wedges removed and subject again checked for maximum jaw amplitude. Frequent checks of jaw amplitude were made as the experiment progressed.

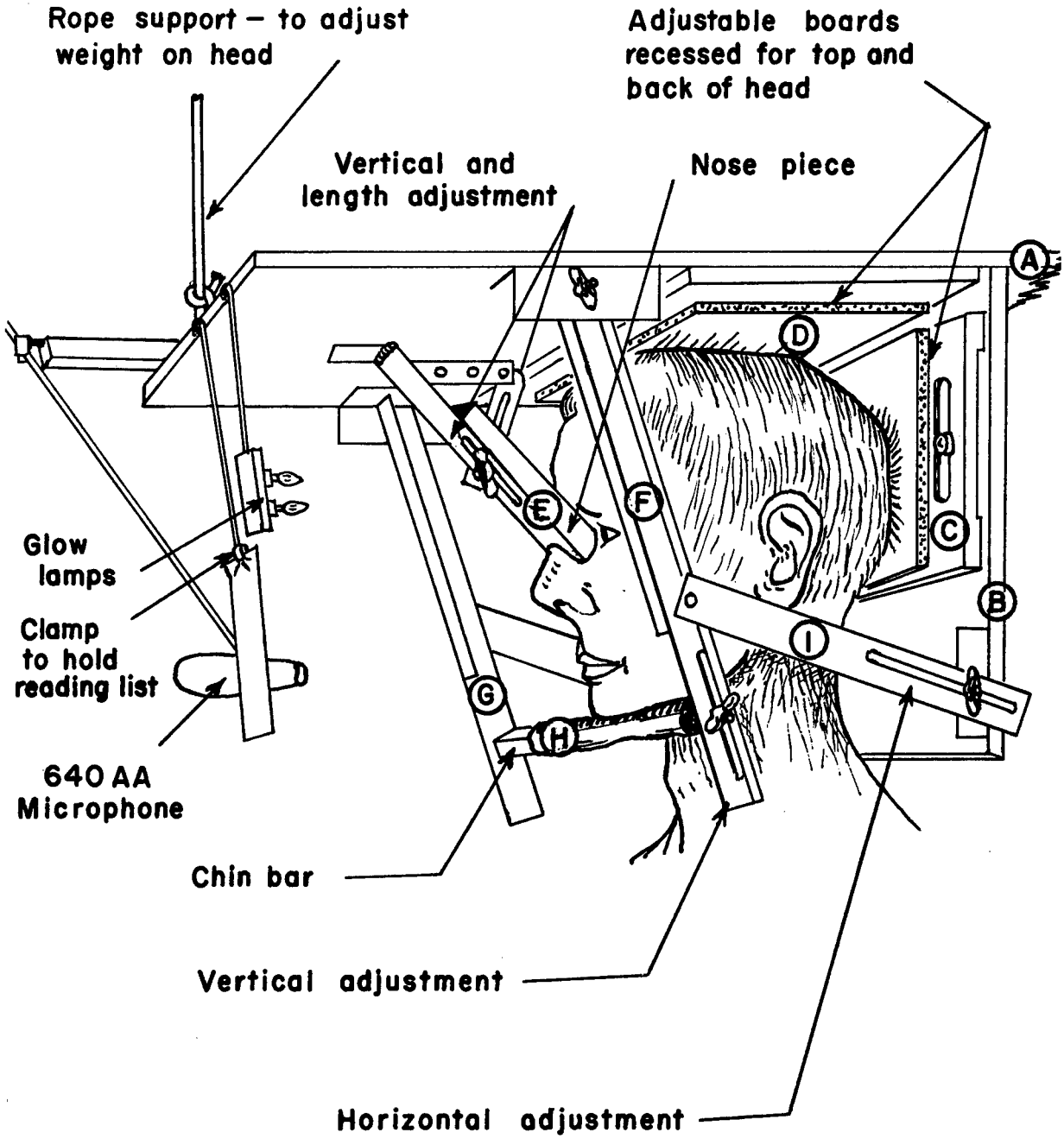
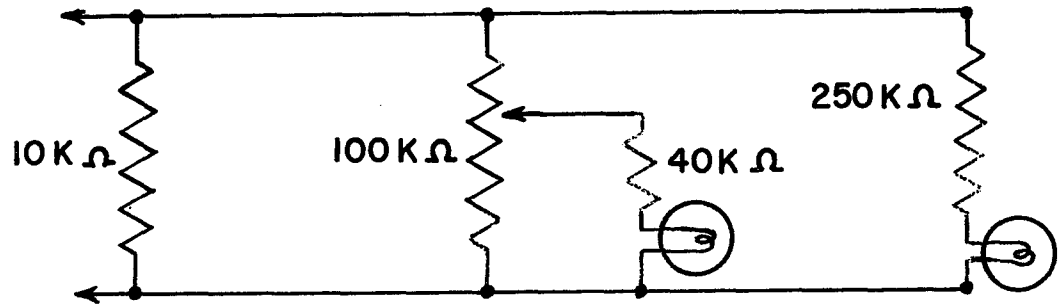


FIGURE 1

Part B. Determination and Control of Loudness Levels:

Simultaneous to the determination of the amounts of jaw restriction various levels of loudness were tried. A low "conventional speaking" level was found to be close to an average intensity of 70 db as measured by the GRC 759 Sound Level Meter placed 12 inches in front of the speaker's lips. A near shouting level was found to be approximately 90 db average. It was found that with a short practice period subjects could maintain an average of 70 db, 80 db and 90 db ± 3 db. In order that the subject could monitor his own loudness level a circuit was designed wherein one neon bulb would glow brightly when speech level was maintained at 70, 80 or 90 db. Another neon bulb would flicker as peak pressures came within 3 db of desired levels. This circuit was connected into the microphone system of the recording equipment. The neon bulbs were located 18 inches in front of and on the same level with the subject's eyes.



Glow lamp circuit

Part C. Apparatus:

(1) 640AA Condenser Microphone
(2) Condenser Microphone Complement Type 100B
(3) Spencer Kennedy Filter Model #302
(4) Hewlett-Packard Voltage Amplifier Model 450A
(5) White Noise Generator
(6) 604 Duplex Altec Speaker
(7) Hewlett-Packard Vacuum Tube Voltmeters
(8) Ampex Recorder Model 302
(9) Siemens Power Amplifier

The speech signal was picked up by 640AA Microphone 12 inches in front of the speaker's mouth and then amplified by preamplifier and fed along low impedance lines to a Condenser Microphone Complement and there amplified further. Signal was then fed from the output at the Microphone Complement into a high pass filter which cut out frequencies up to 150 cps. This filtered out extraneous low frequency room noises and

60 cycle hum. Parallel to the filter input a Siemens Power Amplifier with a high output impedance (in order to obtain sufficient voltage necessary to operate glow lamp) was connected to a glow lamp circuit. A voltage amplifier was connected from the output of the high pass filter to overcome the insertion loss. An Ampex Tape Recorder was connected to the voltage amplifier and speech signal was recorded on tape at a speed of 15 inches per second.

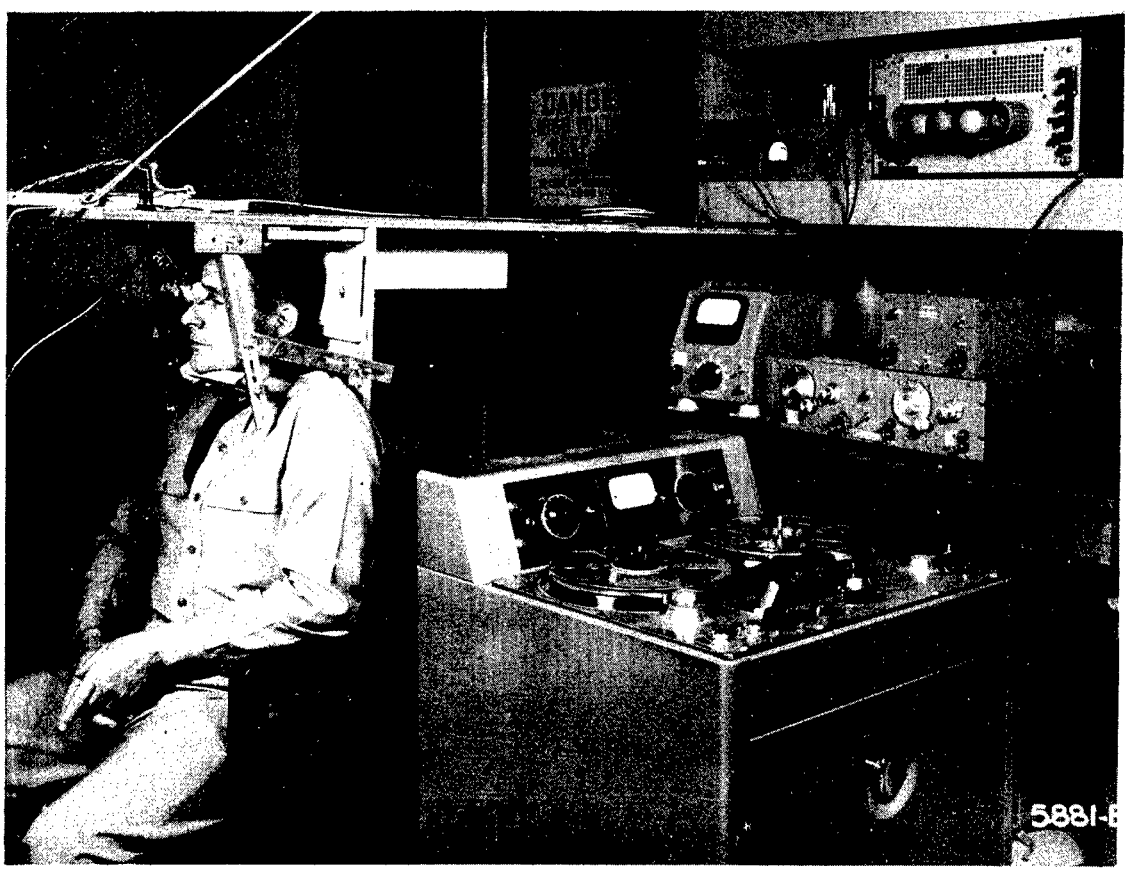


Fig. II Head Holder and Recording Equipment

APPENDIX II

Sample Speaker Form

Form A

Speaker 1

Number 1 swarm canvas quart
Number 2 airport bark tassel
Number 3 group flicker beef
Number 4 legion wonder horn
Number 5 threat deer garden
Number 6 curtain export final
Number 7 rage city all
Number 8 knuckle dress screech

Speaker 2

Number 1 skid mood twist
Number 2 profane thin receive
Number 3 hard fasten anger
Number 4 joke shaft knitting
Number 5 course balance rank
Number 6 lanky horror unfold
Number 7 pipe beast spray
Number 8 drift concern first

Speaker 3

Number 1 feed conclude train
Number 2 virtue hire patch
Number 3 dinner envy rumor
Number 4 spear goal mettle
Number 5 fault birch praise
Number 6 slack kernel drab
Number 7 go lady break
Number 8 chain ten heart

Speaker 4

Number 1 pardon hall double
Number 2 top cruel storage
Number 3 eight dissolve needle
Number 4 fable recline volley
Number 5 shade infect card
Number 6 brain squad tramp
Number 7 plan lift behold
Number 8 glory nut force

Speaker 5

Number 1 crook fair amble
Number 2 brick dim matching
Number 3 shook opal trail
Number 4 flame were relief
Number 5 plot kind sleeping
Number 6 eighty swoop quit
Number 7 world handy dot
Number 8 unfit reverse budget

Speaker 6

Number 1 term hate commit
Number 2 proud waist meaning
Number 3 deflect law jobber
Number 4 tell invite flat
Number 5 faithful suit became
Number 6 rural noon save
Number 7 edge binding prince
Number 8 desk vote young

Speaker 7

Number 1 chisel bond dream
Number 2 forge seal notion
Number 3 verse harvest tight
Number 4 guide jungle blunt
Number 5 pun speed hail
Number 6 eat pad depth
Number 7 wife rocket keep
Number 8 content fork ask

Speaker 8

Number 1 gadget why belt
Number 2 sandy power fit
Number 3 attic main describe
Number 4 cattle heel tare
Number 5 ring option class
Number 6 killer span thimble
Number 7 dozen guard chapter
Number 8 wealth prevent foremost

Speaker 9

Number 1 endure calm absent
Number 2 bacon perfect decide
Number 3 fearful start gown
Number 4 drove thirty roller
Number 5 barge select pride
Number 6 light heading jump
Number 7 gift catch misfire
Number 8 fuel toe odor

Speaker 10

Number 1 recent confront lame
Number 2 perfume gamble what
Number 3 frame scatter harness
Number 4 you treason disgust
Number 5 talent cook musket
Number 6 gone plenty rub
Number 7 center less fox
Number 8 defeat some beach

Speaker 11

Number 1 play bright which
Number 2 robe dash enrage
Number 3 swear ground confess
Number 4 fast caution shower
Number 5 prefer keel hope
Number 6 flare endorse locate
Number 7 ballot rod abound
Number 8 health outline thud

Speaker 12

Number 1 brief define near
Number 2 raid sneeze pension
Number 3 corpse mad zero
Number 4 tree when air
Number 5 bean afraid crane
Number 6 share guess fence
Number 7 denote pain ladder
Number 8 untold hood torment

Sample Listener Forms

VCL:MC Form A

YOUR NAME ..... **DATE** .....

CLASS & WING ..... **POSITION** .....

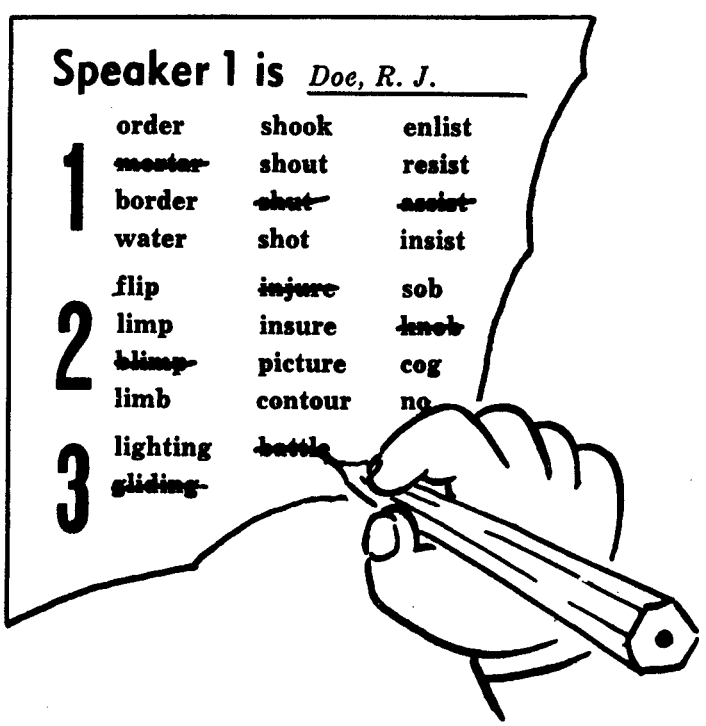
WHEN YOU HEAR....

Number 1
MORTAR SHUT ASSIST

Number 2
BLIMP INJURE KNOB

Number 3
GLIDING BATTLE IGNITE

MARK YOUR PAPER LIKE THIS..



Speaker 1 is .....

	form	campus	court
1	warm	canvas	fort
	swarm	pamphlet	port
	storm	panther	quart
	air force	spark	tassel
2	airport	park	tackle
	air corps	dark	cattle
	airborne	bark	pastel
	group	quicker	beef
3	troop	flicker	beast
	coupe	slicker	beat
	fruit	liquor	beam
	reason	wonder	corn
4	region	blunder	torn
	legion	thunder	horn
	legend	sponsor	born
	stretch	hear	guard
5	threat	steer	hearten
	dread	near	garden
	bread	deer	bargain
	certain	export	file
6	pertain	extort	panel
	person	expert	funnel
	curtain	escort	final
	raid	fitting	owl
7	rate	pretty	call
	range	city	hall
	rage	sitting	all
	uncle	dread	screech
8	buckle	dress	preach
	knuckle	rest	reach
	stucco	red	street

Speaker 2 is .....

	skid	move	swim
1	skin	mood	twin
	hid	food	swift
	hit	smooth	twist
	proclaim	spin	repeat
2	domain	pin	receive
	cocaine	thin	recede
	profane	fin	reprieve
	heart	fasten	angle
3	barge	passion	amber
	lard	fashion	anger
	hard	passing	anchor
	yoke	chat	heading
4	joke	chap	sitting
	choke	shack	knitting
	dope	shaft	fitting
	court	balance	drank
5	cord	ballot	rank
	horse	gallons	ranch
	course	valid	drag
	banking	borrow	unfold
6	flanking	horror	untold
	lanky	father	controlled
	blanket	power	uphold
	pipe	beast	dray
7	pike	beat	grey
	type	meat	spray
	tight	least	pray
	thrift	confirm	verse
8	drip	confer	first
	drift	conserve	burst
	grip	concern	hurt

Speaker 3 is .....

	deed	protrude	train
1	weed	conclude	crane
	seed	construed	strain
	feed	include	terrain
	virtual	hide	pack
2	curfew	five	patch
	virtue	hire	catch
	virgin	fire	cat
	dimmer	envy	rumor
3	dinner	empty	roamer
	thinner	entry	rubber
	tinner	ending	rover
	sphere	gull	petal
4	fear	gall	mettle
	spear	gold	meadow
	beer	goal	settle
	fault	burst	trade
5	vault	hurt	trace
	dog	first	praise
	fog	birch	pray
	black	kernel	graft
6	track	curdle	draft
	slack	turtle	drab
	flak	hurdle	grab
	glow	late	break
7	go	laden	rake
	grow	lazy	great
	goat	lady	grape
	change	pen	hard
8	chain	pin	part
	stain	tent	harsh
	shame	ten	heart

Speaker 4 is .....

	stardom	call	bubble
1	pardon	ball	stubble
	garden	hall	trouble
	autumn	small	double
	top	tool	storage
2	hop	cruel	porridge
	pop	drool	shortage
	prop	cool	story
	eight	revolve	needle
3	ache	involve	fetal
	hate	resolve	eagle
	bake	dissolve	beetle
	able	recline	folly
4	stable	refine	volley
	fable	reclaim	polish
	table	reply	trolley
	gave	effect	hard
5	shade	expect	card
	fade	inspect	cord
	shave	infect	harsh
	strange	wad	plant
6	bring	wash	clamp
	rain	squad	cramp
	brain	squash	tramp
	clad	lift	behave
7	clan	rift	withhold
	plan	drift	revolt
	plant	list	behold
	quarry	such	force
8	glory	touch	fourth
	gory	nut	course
	sorry	butt	horse

Speaker 5 is .....

	cook	fair	annual
1	crook	bare	ample
	brook	care	amble
	book	pair	apple
	brink	skim	action
2	bridge	hymn	matching
	brisk	vim	magic
	brick	dim	smashing
	took	open	trial
3	shook	oboe	file
	shock	opal	frail
	cock	oval	trail
	flame	worm	relieve
4	blame	work	receive
	claim	word	relief
	plane	were	release
	clock	kind	leaping
5	block	pine	sleeping
	plot	fine	creeping
	blot	time	reaping
	eighty	proof	whip
6	aching	hoop	quit
	dainty	group	quick
	baby	swoop	twist
	world	happy	dodge
7	whirl	handy	dark
	wool	candy	dot
	would	envy	dock
	conscript	refer	budget
8	conflict	rehearse	bucket
	assist	reverse	bunion
	unfit	revert	budge

Speaker 6 is .....

	squirm	hate	commit
1	firm	haste	submit
	term	eight	permit
	turn	take	commence
	cloud	waist	feeling
2	crowd	wake	meeting
	proud	wade	feeding
	prod	wait	meaning
	neglect	lost	robber
3	deflect	long	jobber
	reflect	log	harbor
	reflex	law	shopper
	held	invite	blast
4	bell	insight	flat
	fell	inside	flak
	tell	advice	black
	playful	suit	depend
5	faithful	shoot	detain
	fateful	boot	became
	baseball	fruit	retain
	plural	noun	brave
6	neutral	new	stave
	rural	nude	bathe
	ruler	noon	save
	egg	finding	tint
7	edge	binding	print
	hedge	blinding	prince
	head	landing	tense
	desk	both	yawn
8	deck	boat	jump
	death	vote	junk
	debt	quote	young

Speaker 7 is .....

	cheerful	barn	ream
1	drizzle	bond	green
	chisel	born	dream
	fiddle	bomb	scream
	gorge	seal	lotion
2	forge	steel	motion
	ford	feel	ocean
	board	field	notion
	bird	harbor	height
3	birth	Harvard	pipe
	first	harvest	kite
	verse	horrid	tight
	dive	jungle	blunt
4	side	tinkle	blood
	died	shingle	flood
	guide	single	stunt
	pun	seed	sail
5	punch	speed	hail
	pond	bead	rail
	punt	greed	stale
	eat	past	death
6	heat	pass	debt
	heap	path	depth
	deep	pad	deaf
	wipe	rocking	keep
7	wife	locker	feet
	wide	rocket	peep
	white	locket	heat
	contest	fort	add
8	contend	fore	have
	content	force	ax
	contempt	fork	ask

Speaker 8 is .....

	dagger	why	milk
1	gadget	wine	built
	jacket	wire	felt
	jagged	wise	belt
	fancy	collar	fit
2	brandy	pilot	sit
	sandy	tower	spit
	candy	power	fifth
	adding	main	destroyed
3	addict	fame	prescribe
	acting	fade	deprive
	attic	maid	describe
	tattle	field	fair
4	tackle	feel	tare
	paddle	heel	hair
	cattle	eel	pair
	bring	option	clash
5	ring	auction	class
	rink	object	clap
	drink	action	clad
	teller	band	thimble
6	pillar	span	symbol
	killer	spend	temple
	color	bend	simple
	dungeon	barge	capture
7	cousin	dark	captor
	dozen	barred	chapter
	doesn't	guard	captain
	weld	prevent	formal
8	wealth	present	forebode
	whelp	resent	foremost
	well	revenge	promote

Speaker 9 is .....

	insure	calm	abscess
1	endure	come	absent
	obscure	comb	accent
	injure	cob	absurd
	taken	turret	divide
2	bacon	turkey	bedside
	vacant	perfect	deride
	beacon	purpose	decide
	carful	start	found
3	cheerful	dart	down
	fearful	starch	gown
	careful	dark	brown
	throw	dirty	roller
4	grow	thirty	polar
	grove	sturdy	molar
	drove	pretty	colder
	barge	deluxe	pride
5	carve	collect	hide
	large	select	cried
	barb	elect	bride
	like	hitting	jump
6	mike	headache	dump
	might	heavy	junk
	light	heading	drunk
	ship	cash	inspire
7	skip	catch	spitfire
	gift	patch	expire
	shift	pitch	misfire
	duel	coal	motor
8	fuel	tone	mortar
	pool	toe	order
	jewel	cold	odor

Speaker 10 is .....

	region	confront	lame
1	recent	comfort	flame
	regent	convert	plane
	rescind	confirm	blame
	consume	camel	watch
2	presume	gamble	swat
	perfume	sample	squat
	curfew	shamble	what
	crane	scatter	hornet
3	rain	chatter	harness
	train	shatter	harvest
	frame	gather	hardly
	shoe	freedom	distrust
4	cue	reason	discuss
	hue	treason	disgust
	you	freezing	distress
	talent	nook	messkit
5	palace	book	basket
	challenge	hook	cross cut
	pilot	cook	musket
	gone	planting	rub
6	dawn	plenty	rob
	guard	twenty	rug
	darn	pretty	rough
	censor	left	fox
7	sender	let	docks
	center	led	blocks
	slender	less	box
	deceit	come	beat
8	defeat	numb	beach
	receipt	some	speech
	repeat	thumb	meat

Speaker 11 is .....

	sway	bribe	twist
1	slay	bride	which
	play	bite	switch
	pay	bright	twitch
	road	dash	defrayed
2	robe	bash	enrage
	row	gash	engage
	roam	flash	mislaid
	prayer	brown	concept
3	swear	drowned	contest
	where	ground	compress
	square	round	confess
	bat	cautious	sour
4	bask	conscious	scour
	fast	cousin	shower
	fat	caution	tower
	prefer	peel	halt
5	refer	keel	oak
	recur	heal	hope
	preserve	feel	oath
	flare	endure	locate
6	blare	adore	rotate
	clear	indoors	okayed
	glare	endorse	bouquet
	ballad	rod	about
7	ballot	prod	aboard
	balance	ride	around
	valid	fraud	abound
	help	outside	thud
8	felt	combine	bud
	health	alpine	blood
	self	outline	mud

Speaker 12 is .....

	screech	refine	near
1	grief	define	dear
	brief	behind	fear
	breach	decline	mere
	rage	plead	pension
2	raid	please	mention
	raise	sneeze	engine
	rate	siege	tension
	corpse	mad	bureau
3	cord	bad	arrow
	court	bag	here
	caught	man	zero
	three	went	car
4	sea	when	here
	free	wind	error
	tree	win	air
	bean	parade	crave
5	beam	obeyed	terrain
	bead	afraid	train
	bee	appraise	crane
	chair	gassed	bent
6	share	guest	fence
	scare	get	spent
	beer	guess	sent
	steamboat	tame	ladder
7	devote	pain	lather
	demote	paid	matter
	remote	gain	leader
	unsold	put	foreman
8	unfold	could	ferment
	untold	good	torment
	uphold	hood	comment

APPENDIX III

TABLE III

Average and Range of Percent Errors by Speakers

(Note: " = inches)

Speaker A
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	36	36	36	None	25-46	21-67	25-54
Jaw	1/4"	58	35	39	1/4"	46-75	8-46	29-54
Restriction	1/8"	50	43	26	1/8"	38-67	25-62	4-46
	Full	40	37	43	Full	29-50	21-62	25-58

Speaker B
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	29	34	40	None	12-46	12-50	29-46
Jaw	1/4"	42	50	49	1/4"	25-54	46-67	33-71
Restriction	1/8"	45	43	47	1/8"	38-67	12-62	21-71
	Full	39	52	53	Full	8-67	38-71	33-58

Speaker C
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	41	46	25	None	25-67	25-67	17-50
Jaw	1/4"	43	42	43	1/4"	25-67	25-54	25-58
Restriction	1/8"	56	30	23	1/8"	46-71	21-42	4-38
	Full	47	36	50	Full	33-62	17-50	33-67

Speaker D
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	44	35	37	None	25-54	17-54	12-62
Jaw	1/4"	37	39	33	1/4"	21-50	25-50	21-50
Restriction	1/8"	43	35	34	1/8"	25-58	25-50	17-67
	Full	34	35	39	Full	21-50	29-42	25-54

(Note: " = inches)

Speaker E
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	57	53	51	None	42-71	38-67	38-71
Jaw	1/4"	52	56	49	1/4"	38-71	42-71	33-67
Restriction	1/8"	60	59	44	1/8"	42-79	46-75	29-58
	Full	63	50	62	Full	54-75	38-62	42-79

Speaker F
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	46	48	31	None	33-62	21-79	17-46
Jaw	1/4"	48	35	44	1/4"	25-71	12-46	21-71
Restriction	1/8"	61	48	46	1/8"	46-79	25-79	33-58
	Full	56	59	53	Full	38-83	42-75	38-62

Speaker G
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	30	39	38	None	17-42	25-54	25-54
Jaw	1/4"	39	33	42	1/4"	25-50	29-38	38-54
Restriction	1/8"	43	37	36	1/8"	33-54	21-54	25-46
	Full	37	42	48	Full	21-50	25-50	33-54

Speaker H
Number of Listeners 10

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	39	28	44	None	25-50	12-42	29-58
Jaw	1/4"	39	38	36	1/4"	25-58	29-62	21-46
Restriction	1/8"	38	32	35	1/8"	17-58	12-54	17-54
	Full	37	40	40	Full	17-54	17-62	25-67

(Note: " = inches)

Speaker I
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	20	23	33	None	8-38	12-46	17-50
Jaw	1/4"	24	24	35	1/4"	12-50	12-38	12-50
Restriction	1/8"	27	23	23	1/8"	12-42	12-46	12-38
	Full	14	24	30	Full	4-42	12-38	12-46

Speaker J
Number of Listeners 8

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	39	43	60	None	21-67	33-67	42-79
Jaw	1/4"	54	54	52	1/4"	38-62	42-67	38-67
Restriction	1/8"	57	53	45	1/8"	46-71	42-71	29-71
	Full	49	51	47	Full	38-83	29-62	42-54

Speaker K
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	26	32	34	None	12-46	21-54	25-50
Jaw	1/4"	34	31	34	1/4"	25-42	21-42	8-54
Restriction	1/8"	35	31	29	1/8"	25-54	21-46	8-42
	Full	22	28	40	Full	17-25	12-50	33-50

Speaker L
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	45	37	35	None	21-71	17-46	25-46
Jaw	1/4"	35	32	43	1/4"	25-46	25-42	33-54
Restriction	1/8"	33	31	26	1/8"	21-46	12-50	17-38
	Full	24	29	36	Full	8-38	12-46	29-50

(Note: " = inches)

Speaker M
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db	Range 70 db	Range 80 db	Range 90 db
	None	41	35	46	21-58	17-54	25-67
Jaw	1/4"	43	40	35	21-62	25-62	17-54
Restriction	1/8"	39	39	49	21-50	21-58	38-58
	Full	38	48	50	21-50	25-67	42-58

Speaker N
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db	Range 70 db	Range 80 db	Range 90 db
	None	43	49	41	17-62	33-58	25-58
Jaw	1/4"	48	40	48	29-62	25-71	38-58
Restriction	1/8"	53	51	43	33-75	33-71	33-58
	Full	58	46	47	46-79	21-79	33-75

Speaker O
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db	Range 70 db	Range 80 db	Range 90 db
	None	35	20	23	25-54	12-29	4-33
Jaw	1/4"	44	31	28	29-58	21-38	17-42
Restriction	1/8"	31	29	27	12-42	8-54	4-42
	Full	36	40	29	25-50	21-58	4-50

Speaker P
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db	Range 70 db	Range 80 db	Range 90 db
	None	37	32	33	21-50	17-50	21-46
Jaw	1/4"	51	28	37	38-67	17-42	21-50
Restriction	1/8"	41	52	49	25-58	29-67	33-62
	Full	45	51	42	21-62	38-58	29-62

(Note: " = inches)

Speaker Q
Number of Listeners 10

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	33	40	24	None	17-54	25-62	8-46
Jaw	1/4"	--	38	34	1/4"	---	25-54	8-58
Restriction	1/8"	35	40	45	1/8"	25-50	21-58	21-60
	Full	42	45	36	Full	17-58	38-54	25-50

Speaker R
Number of Listeners 10

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	40	35	41	None	21-58	25-50	33-71
Jaw	1/4"	48	48	35	1/4"	33-62	33-75	17-54
Restriction	1/8"	44	43	34	1/8"	33-58	33-54	21-54
	Full	57	40	42	Full	42-67	21-62	33-54

Speaker S
Number of Listeners 8

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	42	35	26	None	17-58	12-50	17-33
Jaw	1/4"	32	28	34	1/4"	29-42	8-42	25-54
Restriction	1/8"	33	26	35	1/8"	21-54	8-33	17-46
	Full	44	37	35	Full	42-50	25-50	25-50

Speaker T
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	56	55	52	None	38-71	29-79	38-62
Jaw	1/4"	55	55	56	1/4"	42-62	38-71	33-75
Restriction	1/8"	69	53	49	1/8"	54-83	29-75	21-67
	Full	62	60	55	Full	38-71	42-67	46-71

(Note: " = inches)

Speaker U
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	42	34	33	None	25-71	21-46	21-54
Jaw	1/4"	46	41	43	1/4"	29-58	29-54	25-54
Restriction	1/8"	34	42	32	1/8"	21-50	33-54	12-50
	Full	36	44	37	Full	12-67	29-54	29-50

Speaker V
Number of Listeners 8

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	42	28	37	None	25-50	21-33	25-54
Jaw	1/4"	47	33	44	1/4"	29-58	25-42	38-54
Restriction	1/8"	41	33	30	1/8"	29-62	17-50	21-38
	Full	42	29	35	Full	17-58	17-46	8-67

Speaker W
Number of Listeners 9

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	54	36	40	None	33-79	29-62	4-38
Jaw	1/4"	47	41	37	1/4"	8-67	17-42	29-54
Restriction	1/8"	38	38	35	1/8"	25-62	25-58	17-50
	Full	39	43	48	Full	12-58	46-62	33-54

Speaker X
Number of Listeners 7

Voice Level		Average 70 db	Average 80 db	Average 90 db		Range 70 db	Range 80 db	Range 90 db
	None	51	45	18	None	38-75	25-54	25-54
Jaw	1/4"	40	30	41	1/4"	33-71	25-54	25-46
Restriction	1/8"	49	43	33	1/8"	29-50	25-46	17-58
	Full	44	53	45	Full	21-58	25-62	33-58